
CLAIMS

WHAT IS CLAIMED IS:

- 1 1. An apparatus for use in a borehole for electrical imaging during rotary drilling
2 comprising:
3 (a) a resistivity sensor having a specified offset from a wall of the borehole;
4 (b) an orientation sensor making a measurement of a toolface angle of said
5 apparatus during continued rotation thereof; and
6 (c) a device for maintaining said resistivity sensor at said specified offset.

- 1 2. The apparatus of claim 1 wherein said resistivity sensor comprises a galvanic
2 sensor.
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- 1 3. The apparatus of claim 1 wherein said sensor is mounted on a pad.
2

- 1 4. The apparatus of claim 1 wherein said sensor is mounted on a rib.
2

- 1 5. The apparatus of claim 1 wherein said sensor is mounted on a stabilizer.
2

- 1 6. The apparatus of claim 1 wherein said sensor further comprises
2 (i) a current electrode for conveying a measure current into said formation
3 through a conducting fluid, and

4 (ii) at least one guard electrode proximate to said current electrode for
5 maintaining focusing of said measure current.
6

1 7. The apparatus of claim 6 wherein said at least one guard electrode focuses said
2 measure current in a direction substantially normal to said borehole wall.
3

1 8. The apparatus of claim 7 wherein said at least one guard electrode surrounds said
2 measure electrode and maintains a focusing of said measure current in a flushed
3 zone of said formation.
4

1 9. The apparatus of claim 7 wherein the at least one guard electrode comprises a
2 plurality of guard electrodes for altering a depth of investigation of said resistivity
3 sensor.
4

1 10. The apparatus of claim 6 wherein said at least one guard electrode comprises a
2 plurality of guard electrodes that create substantially spherical equipotential
3 surfaces *spherical focusing*
4

1 11. The apparatus of claim 1 wherein said sensor further comprises:

- 2 (i) a current electrode for conveying a measure current into said formation,
3 and
4 (ii) a measure electrode spaced apart from said current electrode,

5 the apparatus further comprising a processor for determining from a voltage of
6 said measure electrode and said measure current an indication of a resistivity of
7 said earth formation. *short normal*
8

1 12. The apparatus of claim 8 further comprising monitor electrodes to support the
2 focusing in the presence of non negligible contact impedances.
3

1 13. The apparatus of claim 9 further comprising monitor electrodes to support the
2 focusing in the presence of non negligible contact impedances.
3

1 14. The apparatus of claim 8 wherein further comprising a pad that substantially
2 circumscribes said apparatus, said pad carrying said sensor thereon
3

1 15. The apparatus of claim 14 further comprising monitor electrodes to support the
2 focusing in the presence of non negligible contact impedances.
3

1 16. The apparatus of claim 8 further comprising a controller for maintaining a
2 substantially constant power consumption by said electrodes.
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1 17. The apparatus of claim 12 further comprising a controller for maintaining a
2 substantially constant power consumption by said electrodes.
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1 18. The apparatus of claim 14 further comprising a controller for maintaining a
2 substantially constant power consumption by said electrodes.
3

1 19. The apparatus of claim 14 further comprising a controller for maintaining a
2 substantially constant power consumption by said electrodes.
3

1 20. The apparatus of claim 1 wherein said orientation sensor comprises a
2 magnetometer.
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1 21. The apparatus of claim 1 wherein said orientation sensor comprises an
2 accelerometer.
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1 22. The apparatus of claim 1 wherein said device comprises a stabilizer.
2

1 23. The apparatus of claim 1 wherein said device comprises a steerable rib.
2

1 24. The apparatus of claim 1 wherein said borehole is filled with a substantially
2 nonconducting fluid and wherein said resistivity sensor is capacitively coupled to
3 said earth formation.
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1 25. The apparatus of claim 24 wherein said resistivity sensor makes measurements at
2 a plurality of different frequencies.

3

1 26. The apparatus of claim 1 wherein said borehole includes a substantially non-
2 conducting fluid therein.

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1 27. The apparatus of claim 2 wherein said borehole includes a substantially non-
2 conducting fluid therein and wherein said resistivity sensor coneys a measure
3 current into said formation using capacitive coupling.

4

1 28. The apparatus of claim 1 wherein said resistivity sensor further comprises a
2 shielded dipole.

3

1 29. The apparatus of claim 26 wherein said resistivity sensor further comprises a
2 shielded dipole.

3

1 30. The apparatus of claim 26 wherein said resistivity sensor further comprises a
2 directionally sensitive induction logging tool.

3

1 31. The apparatus of claim 30 wherein said directionally sensitive induction logging
2 tool comprises a quadrupole transmitter.

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1 32. The apparatus of claim 26 wherein said resistivity sensor further comprises a
2 radio frequency microwave transmitter

1 33. The apparatus of claim 26 wherein said resistivity sensor comprises an induction
2 coil.

3

1 34 A system for use in a borehole for determining a resistivity parameter during
2 drilling of a borehole in an earth formation comprising:

3 (a) a bottom hole assembly (BHA) including

4 (i) a resistivity subassembly having a resistivity sensor with a
5 specified offset from a wall of the borehole;

6 (ii) an orientation sensor on said subassembly for making a
7 measurement of a toolface angle of said subassembly during
8 continued rotation thereof; and

9 (ii) a device for maintaining said resistivity sensor at said specified
10 offset.

11 (b) a processor for determining said resistivity parameter from measurements
12 made by said resistivity sensor;

13 (c) a device for drilling said borehole; and

14 (d) conveyance device for conveying said BHA into said borehole.

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1 35. The system of claim 34 wherein said device for drilling said borehole comprises a
2 drill bit.

3

1 36. The system of claim 34 wherein said conveyance device comprises a drill string.

2

1 37. The system of claim 34 wherein said processor is part of said BHA.

2

1 38. The system of claim 34 wherein said processor includes a memory device for
2 storing at least a subset of measurements made by said resistivity sensor.

3

1 39. The system of claim 34 wherein said resistivity sensor comprises a galvanic
2 sensor.

3

1 40. The system of claim 39 wherein said sensor further comprises
2 (i) a current electrode for conveying a measure current into said formation
3 through a conducting fluid, and
4 (ii) at least one guard electrode proximate to said current electrode for
5 maintaining focusing of said measure current.

6

1 41. The system of claim 40 wherein said processor maintains a substantially constant
2 power consumption by said electrodes.

3

1 42. The system of claim 34 wherein said orientation sensor comprises a
2 magnetometer.

1 43. The system of claim 34 wherein said orientation sensor comprises an
2 accelerometer.
3

1 44. The system of claim 34 wherein said device comprises a stabilizer.
2

1 45. The system of claim 34 wherein said device comprises a steerable rib.
2

1 46. The system of claim 34 wherein said borehole is filled with a substantially
2 nonconducting fluid and wherein said resistivity sensor is capacitively coupled to
3 said earth formation.
4

1 47. The system of claim 46 wherein said resistivity sensor makes measurements at a
2 plurality of different frequencies.
3

1 48. The system of claim 34 wherein said borehole includes a substantially non-
2 conducting fluid therein and wherein said resistivity sensor conveys a measure
3 current into said formation using capacitive coupling.
4

1 49. The system of claim 34 wherein said resistivity sensor further comprises a
2 shielded dipole.
3

1 50. The system of claim 34 wherein said resistivity sensor further comprises a
2 directionally sensitive induction logging tool.
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1 51. The system of claim 50 wherein said directionally sensitive induction logging tool
2 comprises a quadrupole transmitter.
3

1 52. The system of claim 34 wherein said resistivity sensor further comprises a radio
2 frequency microwave transmitter
3

1 53. The system of claim 34 wherein said resistivity parameter comprises a resistivity
2 image of said borehole.
3

1 54. A method of determining a parameter of an earth formation during formation of a
2 borehole in said earth formation by a device on a bottom hole assembly (BHA),
3 the method comprising:

- 4 (a) maintaining a resistivity sensor on said BHA substantially at a specified
5 offset from a wall of the borehole;
6 (b) using said resistivity sensor for making measurements indicative of said
7 parameter during continue rotation of said BHA;
8 (c) using an orientation sensor on said BHA for making a measurement of a
9 toolface angle of said BHA during said continued rotation; and
10 (d) using a processor for determining from said measurements said parameter

- 1 55. The method of claim 54 wherein said resistivity sensor comprises a galvanic
2 sensor.
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- 1 56. The method of claim 54 further comprising mounting said resistivity sensor on a
2 pad.
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- 1 57. The method of claim 54 further comprising mounting said resistivity sensor on a
2 rib of said BHA.
3
- 1 58 The method of claim 54 further comprising mounting said resistivity sensor on a
2 stabilizer of said BHA.
3
- 1 59. The method of claim 54 further comprising
2 (i) using a current electrode of said resistivity sensor for conveying a measure
3 current into said formation through a conducting fluid, and
4 (ii) using at least one guard electrode proximate to said current electrode for
5 maintaining focusing of said measure current.
6
- 1 60. The method of claim 59 further comprising using said at least one guard electrode
2 for focusing said measure current in a direction substantially normal to a borehole
3 wall.

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1 61. The method of claim 60 wherein said at least one guard electrode surrounds said
2 measure electrode and maintains a focusing of said measure current in a flushed
3 zone of said formation.

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1 62. The method of claim 59 further comprising using said at least one guard electrode
2 for creating substantially spherical equipotential surfaces *spherical focusing*

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1 63. The method of claim 54 further comprising:

2 (i) using a current electrode of said resistivity sensor for conveying a measure
3 current into said formation,

4 (ii) measuring a voltage of a measure electrode spaced apart from said current
5 electrode; and

6 (iii) using said processor for determining from a voltage of said measure
7 electrode and said measure current said resistivity parameter.

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1 64. The method of claim 60 further comprising using monitor electrodes to support
2 the focusing in the presence of non negligible contact impedances.

3

1 65. The method of claim 61 further comprising using monitor electrodes to support
2 the focusing in the presence of non negligible contact impedances.

3

1 66. The method of claim 60 further comprising a carrying said sensor on a pad that
2 substantially circumscribes said apparatus.
3

1 67. The method of claim 66 further comprising using monitor electrodes to support
2 the focusing in the presence of non negligible contact impedances.
3

1 68. The method of claim 60 further comprising using a processor for maintaining a
2 substantially constant power consumption by said electrodes.
3

1 69. The method of claim 64 further comprising using a processor for maintaining a
2 substantially constant power consumption by said electrodes.
3

1 70. The method of claim 66 further comprising using a processor for maintaining a
2 substantially constant power consumption by said electrodes.
3

1 71. The method of claim 67 further comprising using a processor for maintaining a
2 substantially constant power consumption by said electrodes.
3

1 72. The method of claim 54 wherein said orientation sensor comprises a
2 magnetometer.
3

- 1 73. The method of claim 54 wherein said orientation sensor comprises an
2 accelerometer.
3
- 1 74. The method of claim 54 further comprising using a stabilizer for maintaining said
2 specified offset.
3
- 1 75. The method of claim 54 further comprising using a steerable rib for maintaining
2 said specified offset.
3
- 1 76. The method of claim 54 further comprising:
2 (i) using said BHA in a borehole is filled with a substantially nonconducting
3 fluid, and
4 (ii) capacitively coupling said resistivity sensor to said earth formation.
5
- 1 77. The method of claim 76 further comprising using said resistivity sensor for
2 making measurements at a plurality of different frequencies.
3
- 1 78. The method of claim 76 further comprising using said resistivity sensor for
2 making measurements at two frequencies.
3
- 1 79. The method of claim 77 further comprising using said processor for performing a
2 multi-frequency focusing of said measurements.

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1 80. The method of claim 54 wherein said borehole includes a substantially non-
2 conducting fluid therein.

3

1 81. The method of claim 55 further comprising:

2 (i) using said BHA in a borehole is filled with a substantially nonconducting
3 fluid, and

4 (ii) capacitively coupling said resistivity sensor to said earth formation

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1 82. The method of claim 54 wherein said resistivity sensor further comprises a
2 shielded dipole.

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1 83. The method of claim 80 wherein said resistivity sensor further comprises a
2 shielded dipole.

3

1 84. The method of claim 80 wherein said resistivity sensor further comprises a
2 directionally sensitive induction logging tool.

3

1 85. The method of claim 84 wherein said directionally sensitive induction logging
2 tool comprises a quadrupole transmitter.

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1 86. The method of claim 80 wherein said resistivity sensor further comprises a radio
2 frequency microwave transmitter.
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1 87. The method of claim 54 further comprising using an induction coil as said
2 resistivity sensor.
3

1 88. The method of claim 87 further comprising using said processor for determining
2 an inductance of said induction coil.
3

1 89. The method of claim 86 further comprising using said processor for determining
2 an extent of a fluid invasion of the earth formation.
3

90. The method of claim 54 wherein said orientation sensor comprises a
magnetometer